PCT/IB 04 / 02369
(15.07.04)

The Patent Office

INVESTOR IN PEOPLE

The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

PRIORITY DOCUMENT

SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

REC'D 15 JUL 2004

WIPO PCT

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

Re-registration under the Companies Act does not constitute a new legal entity but merely subjects the company to certain additional company law rules.

Signed *K Behan*

Dated 20 April 2004

24JUL03 E824983-1 D02879
P01/7700 0.00-0317305.1

Patents Form 1/77

[illegible]ts Act 1977
([illegible] 16)

THE PATENT OFFICE
B
24 JUL 2003
NEWPORT

The Patent Office

1/77

Request for grant of a patent

(See notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

24 JUL 2003

The Patent Office

Cardiff Road
Newport
Gwent NP10 8QQ

1.	Your reference	PHGB 030120GBP
2.	Patent application number *(The Patent Office will fill in this part)*	0317305.1
3.	Full name, address and postcode of the or of each applicant (*underline all surnames*)	KONINKLIJKE PHILIPS ELECTRONICS N.V. GROENEWOUDSEWEG 1 5621 BA EINDHOVEN THE NETHERLANDS
	Patents ADP Number (*if you know it*)	07419294001
	If the applicant is a corporate body, give the country/state of its incorporation	THE NETHERLANDS
4.	Title of the invention	IMPROVEMENTS IN OR RELATING TO PLANAR ANTENNAS
5.	Name of your agent (*if you have one*)	
	"Address for service" in the United Kingdom to which all correspondence should be sent (*including the postcode*)	Philips Intellectual Property & Standards Cross Oak Lane Redhill Surrey RH1 5HA
	Patents ADP number (*if you know it*)	08359655001
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and (*if you know it*) the or each application number	Country / Priority Application number / Date of filing
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application / Date of filing (*day/month/year*)
8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? (*Answer "Yes" if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	YES

Patents Form 1/77

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document.

Continuation sheets of this form	
Description	9
Claims(s)	2
Abstract	1
Drawings	5

10. If you are also filing any of the following, state how many against each item:

Priority Documents

Translations of priority documents

Statement of inventorship and right to grant of a patent (*Patents Form 7/77*)

Request for preliminary examination and search (*Patents Form 9/77*)

Request for substantive examination (*Patents Form 10/77*)

Any other documents (*Please specify*)

11. I/We request the grant of a patent on the basis of this application.

Signature

Date 23/7/2003

12. Name and daytime telephone number of person to contact in the United Kingdom — 01293 81 5438 — A G WHITE

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

a) *If you need help to fill in this form or you have any questions, please contact the Patent Office on 0645 500505.*

b) *Write your answers in capital letters using black ink or you may type them.*

c) *If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.*

d) *If you have answered "Yes" Patents Form 7/77 will need to be filed.*

e) *Once you have filled in the form you must remember to sign and date it.*

f) *For details of the fee and ways to pay please contact the Patent Office.*

DESCRIPTION

IMPROVEMENTS IN OR RELATING TO PLANAR ANTENNAS

The present invention relates to improvements in or relating to planar antennas, particularly, but not exclusively, to dual band antennas for use in portable telephones. Such telephones may operate in accordance with the GSM and DCS 1800 standards.

PIFAs (Planar Inverted-F Antennas) are used widely in portable telephones because they exhibit low SAR (Specific Adsorption Ratio) which means that less transmitted energy is lost to the head and they are compact which enables them to be installed above the phone circuitry thereby using space within the phone housing more effectively.

A perspective diagrammatic view of a PIFA 10 is shown in Figure 1 of the accompanying drawings. The PIFA 10 is separated from a printed circuit board (PCB) 12 by a dielectric 14 which in the illustrated example is air. Typically electronic components in rf shields (otherwise called rf cans) 18 are mounted on both sides of the PCB 10 and an electrically conductive ground plane 16 surrounds these components and covers the remaining area of the PCB 12.

The PIFA 10 comprises a patch having a slot 20, one end 22 of which is closed and the other end 24 of which opens into the upper edge of the patch. The slot itself comprises four interconnected rectilinear sections 25, 26, 27 and 28 extending orthogonally with respect each other. The slot 20 divides the patch into a central area 30 and a generally U-shaped area 32 which surrounds the central area 30. Both areas extend from a common base area 34. A feed tab 36 is connected at one end to a corner of the base area 34 and at its other end it is connected to components (not shown) mounted on the PCB 12. A shorting tab 38 is connected at one end to a corner of the base area 34 and the open end of the slot 20 and at its other end it resiliently contacts the ground plane 16.

The conventional view of structures such as that shown in Figure 1 is that dual band operation is achieved by incorporating low frequency and high frequency resonators, namely the element formed by the central area 30 and the element formed by the U-shaped area 32, respectively, in the same structure. The slot 20 is considered to separate these resonators, while allowing a common feed point 36.

A perceived drawback of mounting PIFAs inside the housings of portable telephones and locating them just under the outer cover is that they are very susceptible to detuning by a person holding the telephone. The detuning appears to be associated with the antenna and the PCB or with the slot.

An object of the present invention is to mitigate the problem of detuning the antenna by the user.

According to a first aspect of the present invention there is provided a planar antenna assembly comprising a printed circuit board (PCB) having a ground plane and rf circuitry thereon, a patch antenna, means for mounting the patch antenna such that it is spaced from the ground plane, and a feed for coupling the patch antenna to the rf circuitry, the feed comprising components for reactively tuning the antenna by tuning a relatively lower frequency inductively and a relatively higher frequency capacitively.

According to a second aspect of the present invention there is provided a communications apparatus comprising a housing containing a printed circuit board (PCB) having a ground plane and rf circuitry thereon, a planar antenna spaced from the ground plane, a dielectric between the PCB and the planar antenna, and a feed coupling the planar antenna to the rf circuitry, the feed comprising components for reactively tuning the antenna by tuning a relatively lower frequency inductively and a relatively higher frequency capacitively.

According to a third aspect of the present invention there is provided a rf module comprising a printed circuit board (PCB) having a ground plane and rf circuitry thereon, a planar antenna spaced from the ground plane, a dielectric in a space between the PCB and the planar antenna, and a feed

coupling the planar antenna to the rf circuitry, the feed comprising components for reactively tuning the antenna by tuning a relatively lower frequency inductively and a relatively higher frequency capacitively.

The present invention is based on an alternative view of dual band operation of slotted PIFAs. This alternative view is that a PIFA of the type shown in Figure 1 has a single resonance between the two required frequencies. Dual band behaviour is achieved by reactive tuning of the slot, which acts approximately (dependent on the antenna size) as a quarter-wave transmission line close to the resonant frequency of the antenna. This alternative view shows that the slot can be replaced by discrete or distributed component(s), for example a parallel tuned L-C circuit, transmission line or any other predominantly reactive network, for example a filter, that is (or are) located on a part of the antenna structure that is not subject to detuning by the user holding the portable phone.

The present invention will now be described, by way of example, with reference to the accompanying drawings, wherein:

Figure 1 is a perspective diagrammatic view of a slotted PIFA,

Figure 2 is a perspective view of a portable communications apparatus made in accordance with the present invention,

Figure 3 is a diagrammatic perspective view of the reverse side of a planar antenna in which the feed includes a series connected parallel L-C circuit,

Figure 4 is a diagrammatic perspective view of a PCB and PIFA in which a parallel L-C circuit is connected in series with the output of the rf circuitry,

Figure 5 is a diagrammatic perspective view of the reverse side of a planar antenna in which the feed includes a transmission line,

Figure 6 is a diagrammatic perspective view of the reverse side of a planar antenna in which the feed includes a reactive network in the form of a filter,

Figure 7 is a diagram of a PIFA and PCB with a loaded shorting pin and its equivalent radiating and balanced mode representations,

Figure 8 is a perspective diagrammatic view of a tri-fed PIFA,

Figure 9 is a S_{11} plot of a PIFA configuration shown in Figure 8 without the slot and with equal feeds,

Figure 10 is a S_{11} plot of the PIFA configuration shown in Figure 8 in the open radiating, balanced and sum modes, and

Figure 11 is a S_{11} plot of the PIFA configuration shown in Figure 8 with the feeds 1 and 2 being cophased and the feed 3 removed.

In the drawings the same reference numerals have been used to indicate corresponding features.

As Figure 1 has been described in the preamble of this specification it will not be repeated here.

Figures 2 and 3 illustrate a portable communications apparatus, such as a portable radiotelephone, comprising a housing 40 which contains a PIFA 10 coupled by a feed tab 36 to the rf circuitry (not shown) mounted on the PCB 12. A shorting tab 38 resiliently contacts the ground plane 16 on the PCB 12. The shorting tab 38 performs an impedance transformation. A parallel LC circuit 42 mounted on the reverse side of the antenna or a substrate carrying the antenna is connected in series between the feed tab 36 and a feed through pin 46 on the planar antenna. In practice the feed through pin 46 would be close to the feed pin 36 in order not to affect the operation of the antenna 10. The values of the inductance 50 and capacitance 48 of the circuit are selected to reactively tune the antenna. In the case of a dual band antenna for say GSM and DCS frequencies, the lower, GSM frequency is tuned inductively and the higher, DCS frequencies are tuned capacitively. The inductance 50 and capacitance 48 may be discrete or distributed components.

Figure 4 illustrates a first variant of the embodiment shown in Figures 2 and 3 in which antenna 10 is a PIFA and the parallel LC circuit 42 is mounted on the surface of the PCB 12 remote from the antenna 10 and is connected between a rf block circuit 52 and the feed tab 36. A shorting tab 38 is not

required in this implementation as its impedance transforming function is replaced by impedance transforming circuitry in rf circuit block 52.

Figure 5 illustrates a second variant of the embodiment shown in Figures 2 and 3 in which a length of transmission line 54 is mounted on the reverse side of the antenna 10 which in this embodiment is a PILA (Planar Inverted L Antenna). The transmission line 54 is used to reactively tune the antenna. The transmission line 54 may also be provided on the PCB 12 to connect the rf circuit to the feed tab 36. In practice the pin 46 would be close to the feed tab 36.

Figure 6 illustrates a third variant in which any other predominantly reactive network 56, such as a filter, is mounted on the reverse side of the PILA 10 and is used to reactively tune the antenna. The network 56 may also be provided on the PCB 12 to connect the rf circuit to the feed tab 36. In practice the pin 46 would be close to the feed tab 36.

In order to justify the alternative view of dual band operation of slotted PIFAs the following theoretical explanation will be given with reference to Figure 7 of the accompanying drawings. Figure 7 shows a PIFA 10 and a PCB 12 with a loaded shorting tab 38 and its equivalent Radiating mode RAD and Balanced mode BAL representations.

A load can be incorporated in the radiating mode analysis by replacing it with a voltage source of the same magnitude and polarity as the voltage drop across the load.

The input current, I_1 is given by

$$I_1 = I_{R1} + I_B = \frac{V'}{(1+\alpha)Z_R} + \frac{V(1+\alpha)}{Z_B} \qquad (1)$$

where α is the current sharing factor I_{R2}/I_{R1} and the radiating mode voltage is given by

$$V' = V + I_2 Z_L = V + (I_B - \alpha I_{R1}) Z_L \qquad (2)$$

Using the two terms in equation (1) this gives

$$V' = V + \frac{V(1+\alpha)}{Z_B} Z_L - \frac{\alpha V'}{(1+\alpha)Z_R} Z_L \qquad (3)$$

Grouping terms in *V* and *V'* yields

$$V'\left(1+\frac{\alpha Z_L}{(1+\alpha)Z_R}\right)=V\left(1+\frac{(1+\alpha)}{Z_B}Z_L\right) \qquad (4)$$

Simplifying gives

$$V'=V\,\frac{(1+\alpha)Z_R Z_B+(1+\alpha)^2 Z_R Z_L}{(1+\alpha)Z_R Z_B+\alpha Z_L Z_B}. \qquad (5)$$

Thus, a relation is established between the radiating and the balanced mode voltages. A relation can also be derived for the input voltage, V_1, which is given by

$$V_1 = V' + \alpha V \qquad (6)$$

Substituting (5) in (6) and simplifying gives

$$V_1=V\,\frac{(1+\alpha)^2 Z_R(Z_L+Z_B)+\alpha^2 Z_L Z_B}{(1+\alpha)Z_R Z_B+\alpha Z_L Z_B} \qquad (7)$$

The input current can be found from (1) and (5) and is given by

$$I_1=V\,\frac{Z_B+(1+\alpha)Z_L}{(1+\alpha)Z_R Z_B+\alpha Z_L Z_B}+\frac{V(1+\alpha)}{Z_B} \qquad (8)$$

Simplifying yields

$$I_1=V\,\frac{(1+\alpha)^2(Z_L+Z_R)+Z_B}{(1+\alpha)Z_R Z_B+\alpha Z_L Z_B} \qquad (9)$$

The ratio of equations (7) and (9) gives the impedance directly, since both equations have the same denominator.

$$Z_1=\frac{(1+\alpha)^2 Z_R(Z_L+Z_B)+\alpha^2 Z_L Z_B}{(1+\alpha)^2(Z_L+Z_R)+Z_B} \qquad (10)$$

Setting $Z_L = \infty$ gives

$$Z_1=Z_R+\left(\frac{\alpha}{1+\alpha}\right)^2 Z_B \qquad (11)$$

The balanced mode impedance is transformed down (or not at all for a very large current sharing factor) and adds in series with the radiating mode.

This result can be used to explain the operation of slots in the top plate, particularly when the opening is adjacent and close to the feed.

By way of example consider the geometry shown in Figure 8, the illustrated antenna 10 has three feeds F1, F2, F3. The feed F3 and its associated pin are "dummy" elements for the purposes of studying the effect of the slot 20. In the final design they would be removed. In this example the dimensions of the PCB 12 are 100 x 40 x 1 mm and those of the antenna 10 are 30 x 20 x 8 mm.

Figure 9 shows the response of a PILA of the same dimensions but without the slot 20. This is achieved by applying equal amplitude, co-phased signals to each of the feeds F1, F2 and F3. The S_{11} plot covers the frequency band of 800.00 MHz to 3.0 GHz and the markers S1 and S2 indicate the GSM900 and DCS1800 centre frequencies respectively. The response is as expected of a PILA on a PCB of the dimensions given.

The impedance of a PIFA with an open circuit load is given by the equation (11). This can be used to simulate the effect of the slot in the top plate of the antenna 10.

The analysis starts by connecting the feeds F1 and F2 together and applying common and differential voltages to feeds F1 and F2 (together) and to the feed F3. Then equation (11) is used to simulate the condition where the feed F3 is open circuit by way of the summation of the radiating and balanced modes. The resulting S_{11} for all modes is shown in Figure 10. The S_{11} for the Radiating + Balanced modes is shown using "x" and is referenced RAD/BAL, the Balanced mode has been shown using "◊" and is referenced BAL and the Radiating mode has been shown using "•" and is referenced RAD. In Figure 10 the various markers are as follows:

r1	radiating mode, Z_R at GSM centre frequency
r2	radiating mode, Z_R at DCS centre frequency
b1	balanced mode, Z_B at GSM centre frequency
b2	balanced mode, Z_B at DCS centre frequency
rb1	summation of radiating and balanced modes (including $K_{\alpha o}$ multiplication) at GSM centre frequency

rb2 summation of radiating and balanced modes (including $K_{\alpha o}$ multiplication) at DCS centre frequency

At GSM and DCS frequencies the radiating mode impedance is close to that of a PILA without a slot, indicating that the slot has little effect on the radiating mode at these frequencies. There is, however, some effect at higher frequencies.

In the balanced mode the slot simply acts as a reactance, that is, a short circuit transmission line.

It can be seen from Figure 10 that the slot length and the current sharing factor have been optimised such that the summation (series connection) of the radiating and balanced modes gives resonance at both GSM and DCS frequencies. This requires a long slot, partly because the antenna is slightly smaller than is usual.

Figure 11 shows the S_{11} when the feed F3 (Figure 8) and its associated pin are removed (as they would be in the final design). It is observed that the length of the balanced mode transmission line is shortened somewhat, increasing the resonant frequencies, but otherwise the response is nominally the same.

The foregoing analysis gives a new insight into the behaviour of dual-band PIFAs. The antenna does not operate as two connected resonators but as a single resonator that is series reactively tuned by a short circuit transmission line.

This transmission line can be replaced by a parallel L-C resonator, as shown Figures 2 to 4, without fundamentally changing the operation of the antenna. Also since the slot is subject to detuning, for example, when a user puts a finger across the antenna 10 (as very often happens in practice), it is advantageous to use a discrete circuit, which will suffer little or no user interaction.

As shown in Figure 6 the transmission line can also be replaced by any other predominantly reactive network 56.

The present invention is applicable to dual band antennas having a slot replaced by a resonator and to single band antennas in which the slot is replaced by a simple inductance.

In the present specification and claims the word "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. Further, the word "comprising" does not exclude the presence of other elements or steps than those listed.

From reading the present disclosure, other modifications will be apparent to persons skilled in the art. Such modifications may involve other features which are already known in the design, manufacture and use of planar antennas and component parts therefor and which may be used instead of or in addition to features already described herein. Although claims have been formulated in this application to particular combinations of features, it should be understood that the scope of the disclosure of the present application also includes any novel feature or any novel combination of features disclosed herein either explicitly or implicitly or any generalisation thereof, whether or not it relates to the same invention as presently claimed in any claim and whether or not it mitigates any or all of the same technical problems as does the present invention. The applicants hereby give notice that new claims may be formulated to such features and/or combinations of such features during the prosecution of the present application or of any further application derived therefrom.

CLAIMS

1. A planar antenna assembly comprising a printed circuit board (PCB) (12) having a ground plane (16) and rf circuitry thereon, a patch antenna (10), means for mounting the patch antenna such that it is spaced from the ground plane, and a feed (36) for coupling the patch antenna (10) to the rf circuitry, the feed comprising components for reactively tuning the antenna by tuning a relatively lower frequency inductively and a relatively higher frequency capacitively.

2. An antenna as claimed in claim 1, characterised in that the components comprise a series connected, parallel L-C network (42).

3. A communications apparatus comprising a housing (40) containing a printed circuit board (PCB) (12) having a ground plane (16) and rf circuitry thereon, a planar antenna (10) spaced from the ground plane, a dielectric (14) between the PCB and the planar antenna, and a feed (36) coupling the planar antenna (10) to the rf circuitry, the feed comprising components for reactively tuning the antenna by tuning a relatively lower frequency inductively and a relatively higher frequency capacitively.

4. An apparatus as claimed in claim 3, characterised in that the components are carried by the planar antenna.

5. An apparatus as claimed in claim 3, characterised in that the components are mounted on the PCB.

6. An apparatus as claimed in claim 3,4 or 5, characterised in that the antenna is a planar inverted-L antenna (PILA).

7. An apparatus as claimed in any one of claims 3 to 6, characterised in that the components comprise a series connected, parallel L-C network (42).

8. An apparatus as claimed in any one of claims 3 to 6, characterised in that the components comprise a transmission line (54).

9. A rf module comprising a printed circuit board (PCB) (12) having a ground plane (16) and rf circuitry thereon, a planar antenna (10) spaced from the ground plane, a dielectric (14) in a space between the PCB and the planar antenna, and a feed (36) coupling the planar antenna (10) to the rf circuitry, the feed comprising components for reactively tuning the antenna by tuning a relatively lower frequency inductively and a relatively higher frequency capacitively.

10. A module as claimed in claim 9, characterised in that the components are carried by the planar antenna.

11. A module as claimed in claim 9 or 10, characterised in that the components comprise a series connected, parallel L-C network (42).

12. A planar antenna assembly constructed and arranged to operate substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

13. A communications apparatus constructed and arranged to operate substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

14. A rf module constructed and arranged to operate substantially as hereinbefore described with reference to the accompanying drawings.

ABSTRACT

IMPROVEMENTS IN OR RELATING TO PLANAR ANTENNAS

A communications apparatus, such as a portable radiotelephone, comprises a housing (40) containing a printed circuit board (PCB) (12) having a ground plane (16) and electronic components in rf shields (18) thereon. A planar antenna (10), for example a planar inverted-L antenna (PILA), is mounted spaced from the ground plane and a dielectric (14), for example, air, is present in a space between the PCB and the planar antenna. A feed (36) couples the planar antenna (10) to the rf components. The feed comprises components, for example a series connected, parallel L-C resonator circuit (42), a transmission line, or any other predominantly reactive network for reactively tuning the antenna. In the case of a dual band antenna the components are selected so that a lower frequency is tuned inductively and a higher frequency is tuned capacitively. The components, which may be discrete or distributed, are mounted on the PCB or a part of the planar antenna structure which is not subject to detuning by the user in normal operation of the apparatus.

(Figure 2)

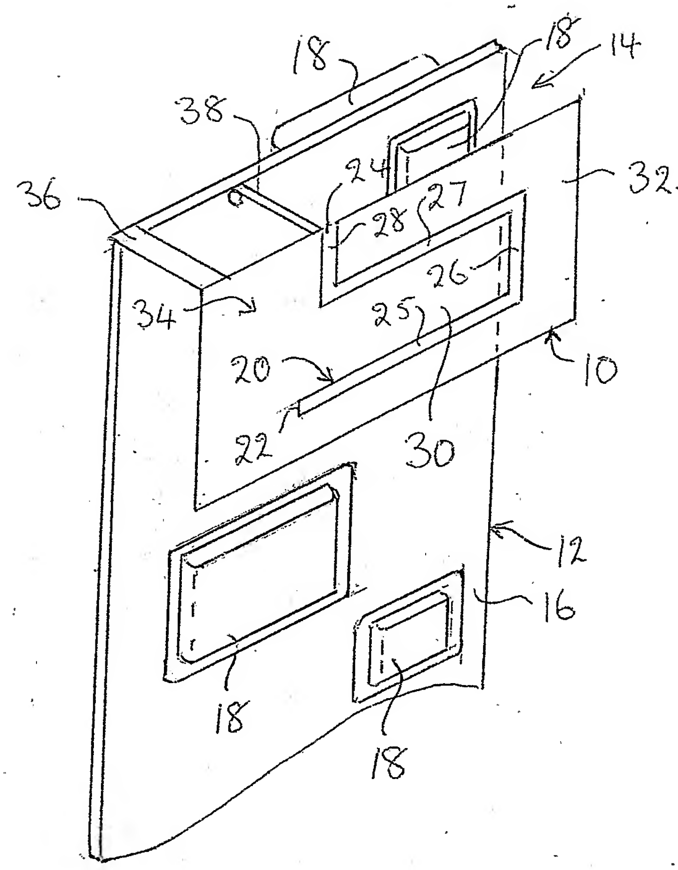

Fig. 1

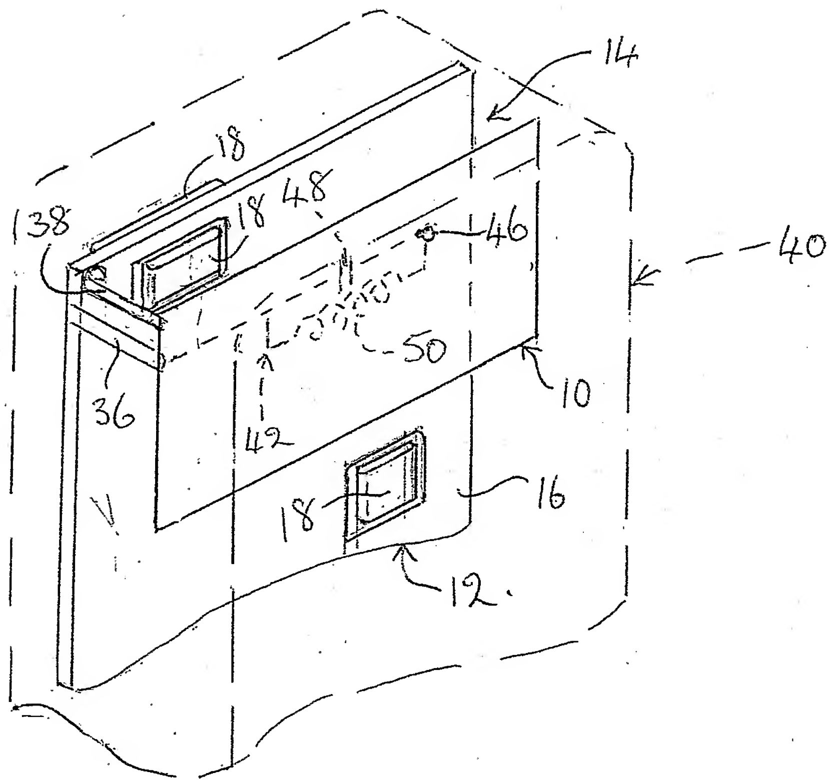

Fig. 2

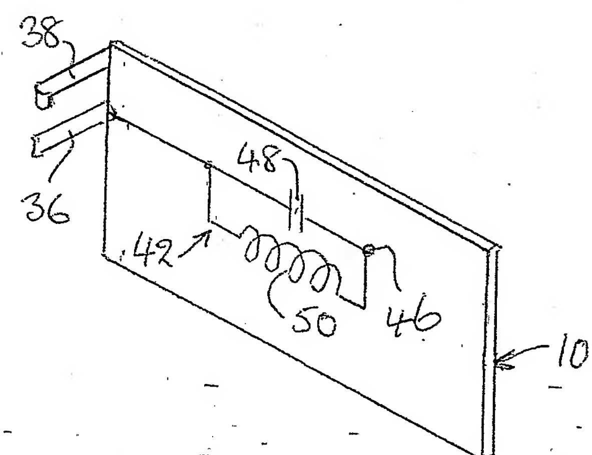

Fig. 3

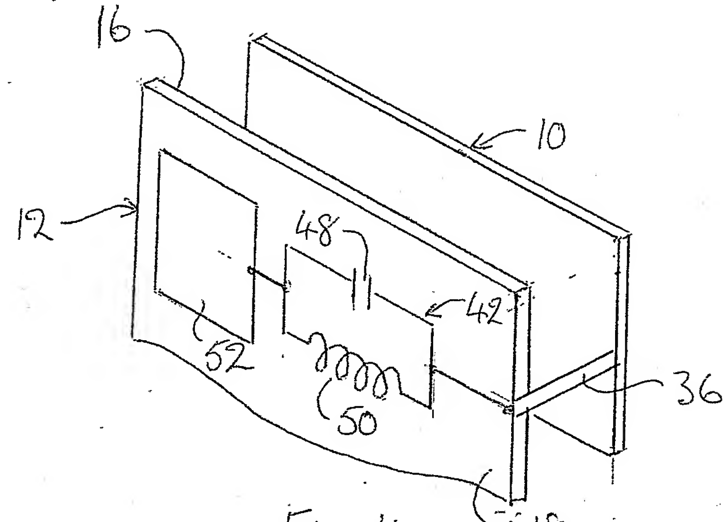

Fig. 4

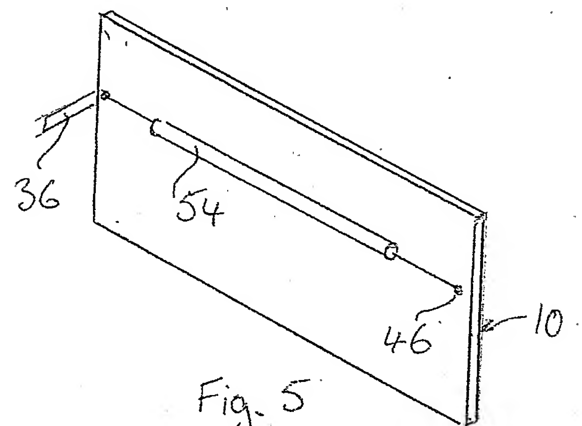

Fig. 5

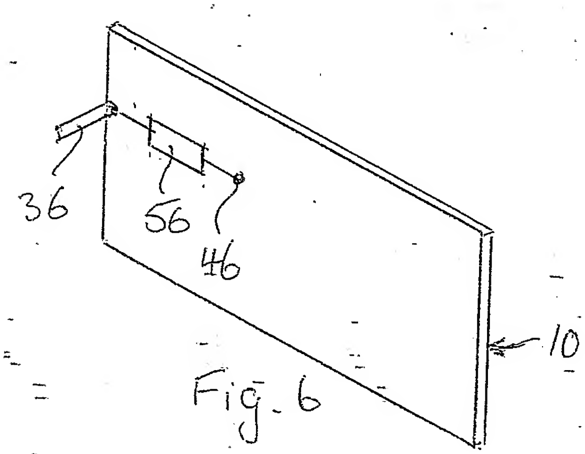

Fig. 6

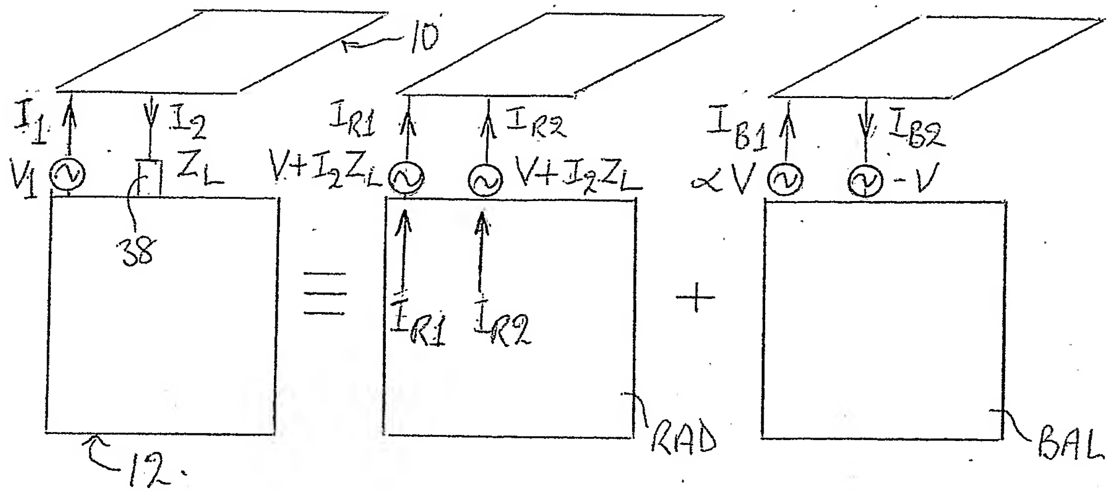

Fig. 7

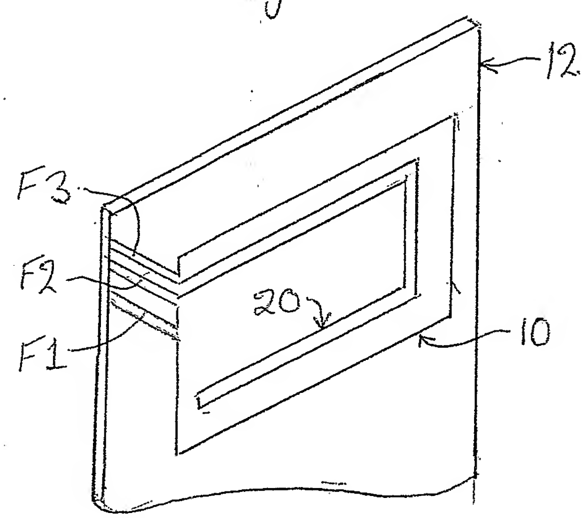

Fig. 8

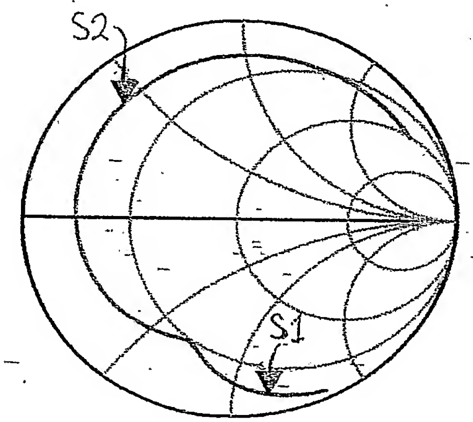

Fig. 9

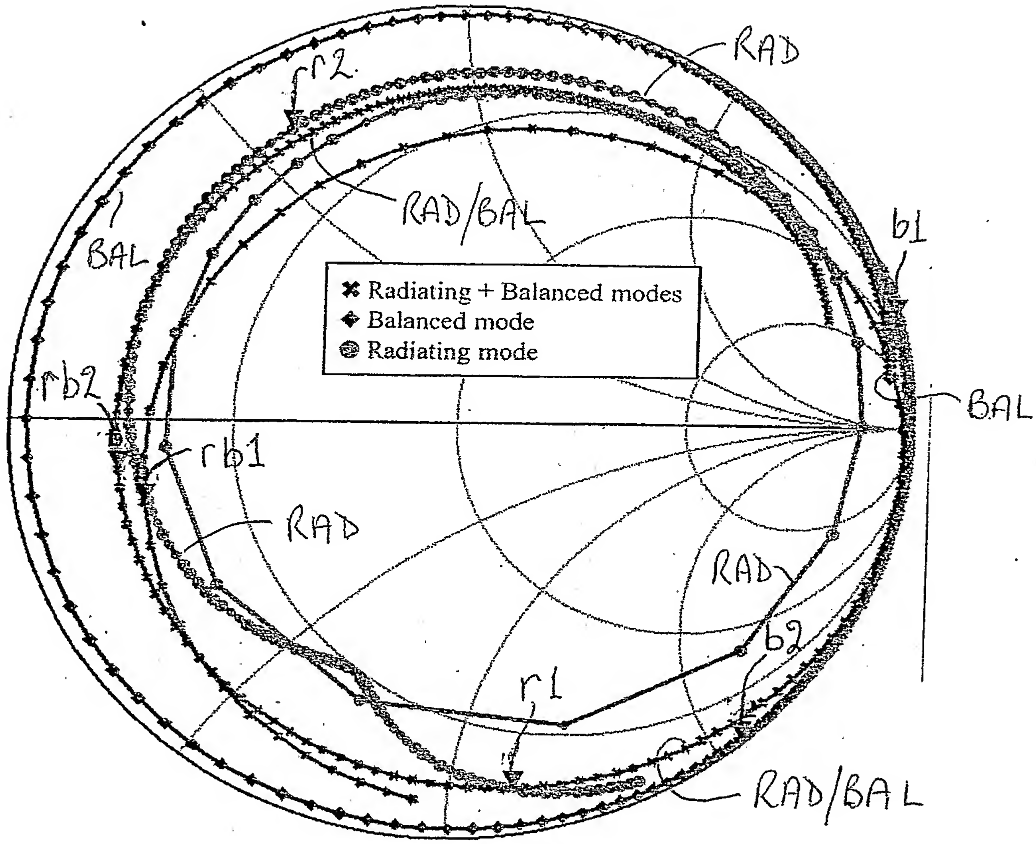
RAD
r2
RAD/BAL
b1
BAL
Radiating + Balanced modes
Balanced mode
Radiating mode
rb2
BAL
rb1
RAD
RAD
b2
r1
RAD/BAL

Fig. 10

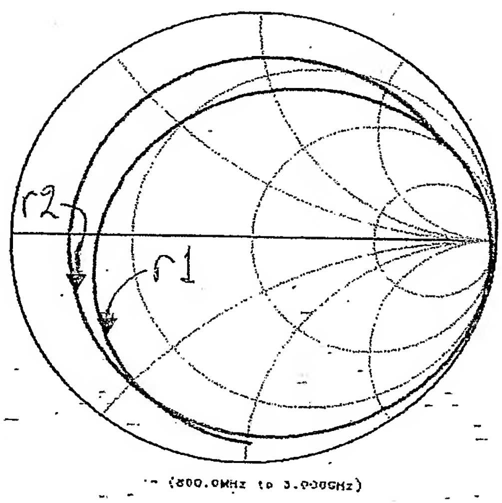
r2
r1
(800.0MHz to 3.000GHz)

Fig. 11